Design, Analysis and Development of static mixer using Additive Manufacturing

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Abstract
The aim of this paper is to increase the mixing efficiency of helical static mixer, customizing the amount of fluid flow and analysing the Fluid flow inside the device (In-line shear flow analysis) is proposed in this article. The design of baffles in the blender has been optimized to get more shear forces between the fluids. In order to reduce the production cost, The whole product is developed using Additive manufacturing with Fused deposition method. In this method the material of the component gets fused while manufacturing that increases the stiffness of the material. The fluid flow inside the device has been analysed computationally. The computational data obtained from the analysis also used to predict the efficiency of mixing occurs in the device. In addition to this application, A dynamic fluid flow controller is placed between the flow of the liquids to customize the amount of the fluid flow. The controller is pivoted on the centre axis of the fluid reservoir of the product. Thus, the analysis of mixed fluid is performed to determine the efficiency of the mixer.

Keywords: *Computational Fluid Dynamics, Static Mixer, Product design, Additive Manufacturing.*

1. Introduction

Static mixers are used in the process of specific elements in a housing for simultaneous mixing in the flow applications. This element uses the applied energy (pressure) as the input to provide blending, dispersion, and heat transfer with minimal energy loss. These kinds of mixers are used in chemical and pharmaceutical industries to boost mixing rates, even with the fluids which consists of high viscosity and density in the medium. In general,Many of the static mixers has the constant fluid flow and the fluids will mixed in the required proportional limit. In this paper, the objective is to increase the efficiency of the static mixer even if it is subjected to the dynamic fluid flow components and also the manufacturing methodology also analysed. In this research, The product is mainly consist of the components of Plunger, Fluid Reservoir, Mixing element (Fluid blender), Mounting, Connector, Dynamic fluid Controller, Inlet and Outlet port. Additionally the component is manufactured by the method of fused deposition in additive manufacturing. In this method, the molten material gets melted and deposited based on the required pattern in X and Y direction by the extrusion head in 3D printer. Due to the process of manufacturing, the material gets fused while cooling period which results in the increased stiffness. On experimentation, The fluids which are filled in the reservoir is pumped towards the inlet of the mounting, here the mounting converges the diverged fluids into the blender. As the convergence occurs, the fluid tends attain the laminar flow. Hence the study of increasing the efficiency of mixing is analysed.

2. Literature Review

Vikhansky, A. (2020). Illustrates that the numerical study of the emulsification process in a high-efficiency vortex has been done. The multiphase Eulerian approach is used to model the two-phase flow, Meanwhile the recently-developed adaptive multiple size-group calculates the droplet size distribution.

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Kwon, B., Liebenberg, L., Jacobi, A. M., & King, W. P. (2019). Heat transfer enhancement of internal laminar flows using additively manufactured static mixers. International Journal of Heat and Mass Transfer, 137, 292-300.

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Hornung, C. H., Nguyen, X., Carafa, A., Gardiner, J., Urban, A., Fraser, D., ... & Tsanaktsidis, J. (2017). Use of catalytic static mixers for continuous flow gas–liquid and transfer hydrogenations in organic synthesis. Organic Process Research & Development, 21(9), 1311-1319.

Jiang, X., Xiao, Z., Jiang, J., Yang, X., & Wang, R. (2021). Effect of element thickness on the pressure drop in the Kenics static mixer. Chemical Engineering Journal, 424, 130399.

Conclusion from the Literature Review

From the above review, The mixing efficiency of the static mixer with various geometries has been studied by Finite element method analytically. The comparison of Kenic and LPD static mixer has been analysed. The efficiency, mechanism and mixing time duration has been also studied by researching on the twist angle of kenic static mixer and slope angle of LPD elements. Then the flow patterns of the fluids are yet to be studied in this article.

3. Experimentation

3.1 Components of the product

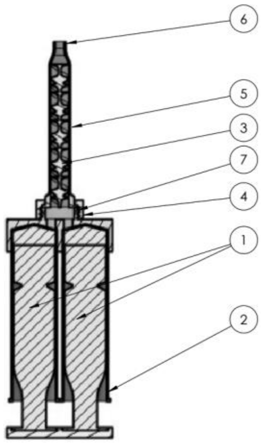

Fig 1. Design of Static Mixer

Table 1Components of the Product

S.No	Components
1	Plunger
2	Fluid Reservoir
3	Mixing Element (Fluid Blender)
4	Connector
5	Mounting
6	Dynamic Fluid Controller
7	Inlet and outlet port

The list of components to be used in the project is shown in the table 1

3.1.1. Plunger

The length of the plunger is 130 mm and thickness of both the ends are 3mm and thicknesses of the supports are 1.5mm. As shown in the Fig.2, The diameter of the smaller end is 20mm while the bigger end is 30mm. The plunger is used to pump the fluid towards the inlet port of the mixer. The pressure is derived as a result of an external force applied on the smaller end of the plunger. This movement of the plunger increases the velocity of the fluid with increase in the pressure. The reversed movement of the plunger makes some vacuum and the air molecules will be filled out. So, only the positive pressurised movement of the plunger will be takes place while processing the mixture of the fluids.

Fig 2. Plunger

3.1.2. Fluid Reservoir

The length of the fluid reservoir is 115mm and the wall thickness is around 1.5mm. Totally the volume of the volume of the reservoir is 81288.71 mm^3. The reservoir holds the fluids either it may be a catalyst or a resin. It can also tends to withstand the force exerted by the fluids and as well as the plunger. It has the flow path for the fluids to flow through its outlet and converge towards the blender through the mounting.

Fig 3. Fluid Reservoir

3.1.3. Mixing Element (Fluid Blender)

Due to consistent pressure applied from the reservoir, The fluid tends to flow towards the blender in accordance with the constant viscosity. The diverged two fluids gets converged mainly due to the presence of this blender. The blender makes the fluid to get fused with one another as a resultant of the constant viscosity and pressure of the fluids from the reservoir through the connector

Fig 4. Blender

3.1.4. Connector

The connector is placed between the reservoir and the mounting to make the fluid to flow without any leakage. It controls the fluid flow by converging the diverged fluids into the blender. Due to the constant velocity and pressure of the fluid, the mixing occurs simultaneously. The overall height of the connector is 35mm and the external thread size is M26mm

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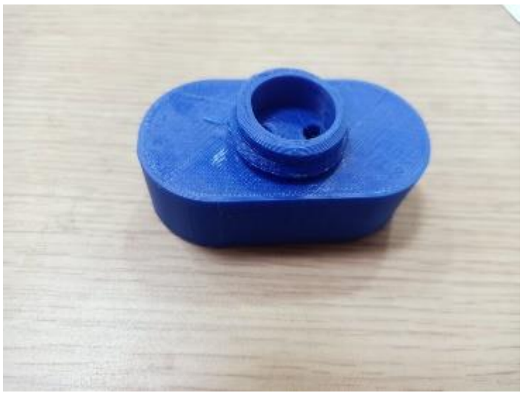

Fig 5.Connector

3.1.5. Mounting

Mainly the mounting converges the two types of diverged fluid into the fluid blender which makes the entire processing due to mixing. It has the threadedsurface from the interior and it holds the connector without any leakage by connecting it towards the blender. The height is 15mm and the wall thickness is 2mm. It binds the joint between two ends of both the connector and the blender.

Fig 6. Mount

3.1.6. Dynamic Fluid flow controller

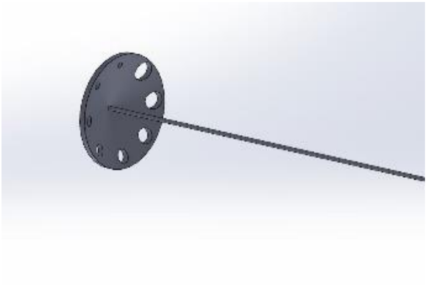

Fig 7. Dynamic fluid flow controller

As it controls the fluid flow dynamically based on the catalyst requirements. The diameter of the ports sequentially varies from 1.5mm to 5mm. During the customization of fluid flow the head of the controller will be rotated based on the pivoted axis. As the diameter of the inlet is varies gradually according to the flow ratio.

4. Manufacturing Methodology

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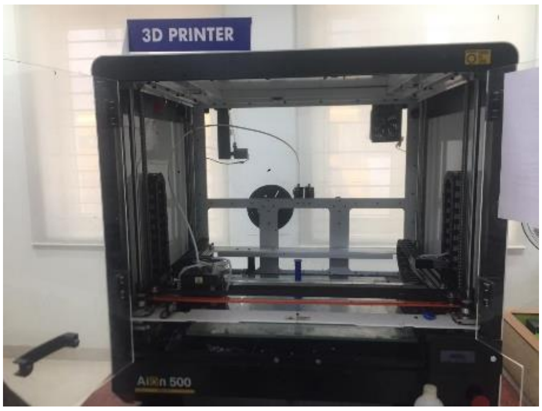

Fig 8. Fused Deposition Modelling

In the metal extrusion 3D printing technology, the base material of thermoplastic continuous filaments can be used.The extruder in the 3D printer head melts the filament and pushes towards the output nozzle.The extruded molten material has been subjected to deposit on the heat bed for an extra adhesion.There are various thermoplastic materials can be used in this type of extrusion, such as Acrylonitrile Butadiene Styrene (ABS), PolyLactic Acid (PLA), High-Impact Polystyrene (HIPS), Thermoplastic PolyUrethane (TPU), and some of the plastics like PolyEther Ether Ketone PEEK or PolyEtherimide PEI.

Table 2 Machine Specifications

S.NO	PROPERTIES	DESCRIPTION
1	Physical Dimension (mm)	955 X 1040 X 925
2	Printable Area (mm^3)	500 X 500 X 500
3	Build Volume (Litre)	125
4	Input Frequency (Hz)	47 - 63
5	Filament Diameter (mm)	1.75
6	Extruder Temperature (°C)	270
7	Build Rate (cm^3/hr)	15-30

5. Conclusion

Hence, the idea of making the static mixer by additive manufacturing is effective in all the aspects in order to design, manufacturing and cost reduction parameters. The additional feature of dynamic fluid flow controller plays the major role in customizing the fluid flow in increasing the efficiency mixing.

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